

**Instructions
for the tool for:
the Extended Smooth Pathway Model
(ESPM)**

- **Reference Values for NDCs**
 - **NDC Calculator**

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The latest version of the tool can be downloaded at: www.save-the-climate.info

Version: 1.3

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1 Basic idea behind the ESPM¹

1. **National budgets:** A predefined **global CO2 budget 2020 – 2100** is **distributed to countries**. The 'Tool_ESPM' offers the use of a weighted distribution key that includes the 'population' and the 'emissions' in a base year (here: 2019). This distribution key makes it possible to map reality with the current emissions of a country and through the population share climate justice.
2. **National paths:** The 'Tool_ESPM' offers the Regensburg Model scenario types RM 1 - 6 to derive plausible **national paths** from a national budget. This scenario types cover the range of possibilities well.

2 Brief introduction to the tool for the ESPM

With this tool you can determine national budgets and plausible national emission paths from this budget.

In the **sheet 'base data'** you can set the basic conditions such as the budgets which are to be met, and the minimum value of national annual emissions (potential for net negative emissions). To determine the remaining national budget a simple weighting model (emissions and population in base year 2019) is offered.

In the **sheet 'reference values'**, you can select a country from the drop-down list, to get an impression of which challenges the chosen country is confronted with, and can then compare these with the offers this country has submitted so far or plans to submit (NDCs). In particular, the **reference values** for 2050 and 2030 appear in this sheet.

In the **sheet 'output countries'** you can create a list of all countries in the world, which gives the **national budgets 2020 - 2100** for a given weighting of the population and **reference values** for the **largest emitters**.

For deriving **national paths** the tool offers the scenario types **RM 1 - 6**. There differ in particular in terms of different assumptions on the trajectory of annual reduction rates resp. reduction amount.

When modifying input data (which the cells shaded in yellow are designated for) or select a other country, you must always execute the **macro** in the **sheet "goal seek"** to adjust the free parameter in the scenarios such as to meet the national budget 2020 - 2100 which is set out in sheet 'base data'.

¹ Inspired by: Raupach, M. R. et al., 2014. Sharing a quota on cumulative carbon emissions. Nature Climate Change, Band 4, pp. 873 - 879.

3 Entries in the sheet 'base data'

I. Entries of data to determine a global budget from 2020 – 2100

In this tool, a global budget 2020 - 2100 is distributed across countries.

In a first step, a global budget 2018 - 2100 is set.

Emissions from 2018 and 2019, AFOLU and CO₂ emissions from international shipping and aviation are deducted from this budget.

global CO₂ budget 2018 - 2100

- CO₂ AFOLU from 2018 on
- CO₂ emissions international aviation and shipping from 2018 on
- (projected) global CO₂ emissions 2018 - 2019

= global CO₂ budget 2020 - 2100 to distribute here

I. a) Global CO₂ budget 2018 – 2100

Input global CO₂ budget 2018 - 2100 based for example on the Special Report of the IPCC October 2018 (see Table 2.2 SR15 in the sheet).

I. b) Global emissions 2018 and 2019

You can enter a rate of change for the expected change in emissions in 2019.

I. c) Global budget 2020 – 2100 without AFOLU and international shipping/aviation (ISA)

AFOLU is the abbreviation used for CO₂ emissions caused by Agriculture, Forestry & Other Land Use. Because it is still difficult to find numbers for individual countries, AFOLU emissions are not considered and therefore need to be deducted.

You can specify a share of the global budget in the tool that is to be reserved for positive AFOLU emissions. The current share of AFOLU emissions is given as information.

Emissions from international shipping and aviation (ISA) also have to be deducted, since attribution to countries is difficult here.

Since this tool is designed to calculate national emission paths for the period 2020 – 2100, the global emissions for the years 2018 and 2019 also need to be deducted.

The result is the global budget, which can be distributed across countries in this tool for the period 2020 - 2100.

II. National CO₂ budget 2020 – 2100

The national budget used here results from the application of a weighted distribution key to the global budget 2020 - 2100. The distribution key includes: the country's share of the global population and global emissions in 2019.

You can specify the weighting of the population here.

You can also enter a freely calculated national budget 2020 - 2100.

III. National minimum emissions

Here you can specify which minimum the national paths can achieve in 2100 (E_{min}). If you specify a negative value, this means net negative emissions.

The specification is made by entering a percentage that will be applied to national emissions in 2019 of the chosen country.

The sheet also shows suggestions for E_{min} based on the illustrative IPCC model paths P1 and P2. For this, the net negative emissions in 2100 in the illustrative model paths of the IPCC SR15 are set

in relation to the global emissions without AFOLU and ISA.

Note: Paths P 3 and P4 have significantly higher net negative emissions.

Please note the basic comments on negative emissions in this sheet.

4 Entries in the sheets ‘country’ and ‘data countries’

If you have downloaded the tool directly from our website, you generally do **not need** to make any **further entries** here.

For the current emissions, we have resorted to data from EDGAR (EU data base; see sheet ‘EDGAR’). Population figures are taken from a UN data base (see sheet “UN-P”).

In order to be able to calculate national emission paths, the emissions of any one country in 2019, the base year, are required that are not yet available.

Projection to 2019 in sheet ‘data countries’ is based in principle on the current figures. The last current value is shown in column P and the average values for the past two years in column Q.

You may embed an individual projection rate in column O for any one country permanently in the sheet ‘data countries’. For some countries we have already embedded an individualised projection rate which you can of course change.

Since the sum of emissions in 2019 must match across all countries and the global value in the sheet ‘base data’, an upper and a lower limit for the projection rate can be specified in the sheet ‘data countries’. You can use the macro provided in the sheet to determine the upper limit so that the values match.

Column N shows the projection rate based on the last actual change and the application of the limits. Column P shows the projection rate ultimately used, taking into account an entered individual value.

This projection for 2019 does not lead to realistic results for every country. For this reason you can either enter your own rate of change or a concrete figure for emissions in 2019 in the sheet “country” for the chosen country. Please delete these entries when you choose a new country. This option should not be used for countries with a large share of global emissions. The input options in the sheet ‘data countries’ should be used for these countries.

5 Determination of national emission paths

5.1 Where and how the national paths are determined

National emission paths are determined using the scenario types RM 1 – 6.

The paths are calculated in the **sheet 'RM'** (the results are transferred to the **sheet 'country'**).

The **paths** are **determined** basically by setting the **annual** rates of **change** (RM 1 - 5) or the annual constant reduction amount (RM-6). This determination of paths through the annual changes represents an **innovative element** of the Regensburg Model scenario types **RM 1 – 6**.

In scenarios RM 2 - 5, the rate of change for 2020 (*RR_20*) is an input value in the sheet 'goal seek'. The last actual change rate of the chosen country is given in this sheet as an orientation.

In scenarios RM 1 - 5 for the transition to **net negative emissions**, a constant reduction amount is applied from a predefined threshold (*TV*). The last reduction amount before the threshold is reached is then used. The **change of method** is necessary, because net negative emissions cannot be implemented by determining the reduction rates. You set the threshold value by entering a percentage. This percentage is applied to emissions of the chosen country in the base year 2019. Different threshold values can be set for scenario type RM-1 and scenario types RM 2 - 5. In scenario type RM-1, a higher threshold value can be useful in order to achieve faster net negative emissions. By entering the *TV*, you can freely choose when the method should be changed.

If the path reaches *E_min*, this value is continued until 2100.

In the **sheet 'goal seek'** the **free parameter** of the respective scenario is determined so that the national budget 2020 - 2100 is adhered to (target value search). The macro 'goal seek' in this sheet uses the target value search integrated in Excel.

This usually leads to the following **three phases** for determining the paths:

1. Application of the annual reduction rates (RM 1 - 5) or the annual reduction amount (RM-6).
2. Annual emissions less than or equal to *TV*: The last annual absolute reduction is continued.
3. Minimum for the annual emissions (*E_min*) that you specify in the sheet 'base data' will be applied until 2100.

These three phases can be found in the formula for the annual emissions in the individual scenario types in the sheet 'RM'.

5.2 Scenario types RM 1 – 6

The scenarios differ based on the assumptions about the annual reductions:

RM-1-const: A **constant annual reduction rate** is assumed.

RM-2-exp: An **exponential increase** of the annual reduction rates is assumed. The initial reduction rate for 2020 (*RR_20*) must be entered (in this scenario type, no positive change rate 2020 can be used). The reduction rate is escalated annually. Initially, the reduction rates increase² less than proportionally.

RM-3-lin: A **linear increase** of the annual reduction rates is assumed. For the year 2020, an **initial value** (*RR_20*) must be set.

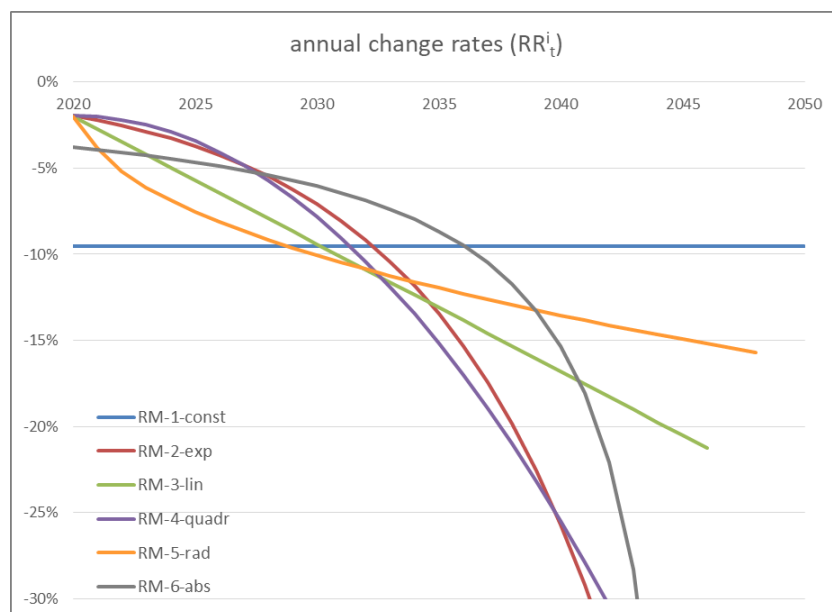
² “Rising reduction rates” are to be understood here in such a way that the absolute amount increases.

RM-4-quadr: An **exponential increase** of the annual reduction rates is assumed. A **quadratic formula** for the annual reduction rates is used. The initial value (RR_{20}) must be set. Initially, the reduction rates increase less than proportionally.

RM-5-rad: A **radical formula** for the annual reduction rates is used. The initial value (RR_{20}) must be set. Initially, the reduction rates increase more than proportionally.

RM-6-abs: A **constant annual reduction amount** is used. This scenario type starts with a relatively high reduction rate. Then the reduction rates initially increase less than proportionally and slowly, in the end increasing very quickly.

The following figure shows an example of the property of the scenario types:



Basic Findings:

The scenario types **RM 1 - 6** cover the **range of possibilities** well. Of course there are countless other ways to define functions. It would then have to be checked whether they deliver significantly different results and whether they are relevant in any way.³

Budget characteristics of CO₂: Basically, the lower the reduction rates⁴ at the beginning and the slower they rise at the beginning, the stronger they have to rise later and the higher the overshoot (depending on the specified value for E_{min}).

Note:

In the Regensburg Model in which national paths are derived from a global path with the help of the Regensburg Formula we use these scenario types RM 1 – 6 to derive global emission paths from a global budget. In another tool, we decoupled the determination of global paths with these scenario

³ This assessment is supported by the fact that the scenario types RM-2 and RM-4 lead to very similar results with a tight budget. This shows: if an initially less than proportionately and low increase is desired as a property (RM-2 and RM-4), then the results do not differ significantly, despite different functions, with a tight budget.

⁴ "Lower reduction rates" should be understood in the sense that e.g. -1.5% less (less challenging) than -2.5%. In purely mathematical terms, of course, -2.5% is less than -1.5%.

types from a given global budget. The tools can also be downloaded at: <http://www.save-the-climate.info>. The approach of assumptions about the annual change in emissions to determine the emission pathways seems particularly useful when politically deciding on emission paths.

5.3 Formulae ESPM

5.3.1 Formulae scenario types RM 1 – 5

$$E_t = \begin{cases} \max(E_{min}; E_{t-1} * (1 + RR_t)) & \text{for } E_{t-1} > TV \\ \max(E_{min}; E_{t-1} + (E_{t-1} - E_{t-2})) & \text{for } E_{t-1} \leq TV \end{cases}$$

where:

E_t emissions of the chosen country in the year t (here: 2020 – 2100)

E_{min} minimum emissions of the chosen country; defined in the sheet 'base data'

TV threshold value; defined in the sheet 'goal seek'

The reduction rates in the individual scenario types are based on the following formulae:

RM-1-const: $RR_t = a = \text{constant}$

RM-2-exp: $RR_t = RR_{t-1} * (1 + a)$; constraint: $a \geq 0$

RM-3-lin: $RR_t = RR_{t-1} + a$; constraint: $a \leq 0$

RM-4-quadr: $RR_t = a * (t - 1 - BY)^2 + RR_{BY+1}$; constraint: $a \leq 0$

RM-5-rad: $RR_t = \begin{cases} RR_{BY+1} & \text{for } t = BY + 1 \\ a * \sqrt{t - 0.5 - (BY+1)} + RR_{BY+1} & \text{for } t > BY + 1; \text{ constraint: } a \leq 0 \end{cases}$

The free parameter a is determined for each scenario type using the target value search integrated in Excel ("goal seek").

5.3.2 Formula scenario type RM-6

$$E_t = \max(E_{min}; E_{t-1} + RA)$$

The free parameter RA is determined using the target value search integrated in Excel ("goal seek").

5.4 Macros in the sheet 'goal seek'

The macro 'goal seek' tries to determine the free parameter in the scenario (row 12 or 13) so that the national budget (row 16) is adhered to (► row 15 = row 16). The macro also ensures that the above-mentioned constraints for the free parameter are met.

If this does not work straight away, the macro tries to find a solution with a lower rate of change for 2020 (for example: -2.5% instead of -2%). The start value you specified is therefore changed. If a solution cannot be found either, the macro will inform you and advise you to change the start value for 2020 more significantly or to change the threshold value (TV).

The macro also tries in scenario RM-1 that the minimum value (E_{min}) specified in the sheet 'base data' is reached (► row 18 = row 19). If this does not succeed straight away, the macro increases the threshold value (TV) in the RM-1. If E_{min} can still not be reached, the original TV will be reset.

The following **additional macros** are offered:

Macro 'copy':

If you want to use the same start change rate 2020 in scenarios RM 2 - 5, you can enter this at the intended position and copy it with this macro in RM 2 - 5.

Macro 'goal seek RM-6':

This macro carries out the determination of the free parameter (constant reduction amount) only for RM-6. Experience has shown that 50% of the resulting rate of change 2020 in the RM-6 represents a good starting value for the scenarios RM 2 - 5. This value is therefore stored in the copy field and can then be transferred with the macro 'copy'.

Macro 'fine-tuning RR_20':

With this macro you can fine-tune the rate of change for 2020 for individual scenarios. After the start, the macro queries which scenario (RM 2 – 5) you want to fine-tune. The macro also queries how many percentage points it should search for a further solution from the entered start value. The 2020 rate of change will be reduced in 0.01 steps. If the macro finds a solution, it takes the lowest value in the specified range. Before this macro can be used, a solution must already exist in the scenario.

6 Reference values for every country in the world

In the **sheet 'reference values'**, any country in the world may be chosen from the drop-down list.

Above this sheet you will see whether the target value search must be carried out in the sheet 'goal seek'.

In this sheet, it is primarily the ratio of emissions of one country in 2030 resp. 2050 (reference points, target year) in comparison with the reference years 1990 resp. 2010 in the relative scenario which is shown as a **reference value**.

The **national budgets** and the **national net negative emissions** are also given.

In the **sheet 'output countries'** you can create a list of all countries in the world, which gives the **national budgets** 2020 - 2100 for a given weighting of the population and **reference values** for the **largest emitters**. The scenario type RM-5-rad is used for the reference values for the largest emitters. This macro also performs the target value search (goal seek). The start change rate 2020 is 50% of the change rate that results in the scenario type RM-6-abs.